Semi-annual Eos Contract Report -- Report #18

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Remote Sensing Group (RSG), Optical Sciences Center (OSC) at the University of Arizona

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Introduction: This report contains ten sections. Each section presents a different aspect of work performed under our contract. If appropriate, each section covers five areas; task objective, work accomplished, data/analysis/interpretations, anticipated future actions, problems/corrective actions. The ten sections are: 1) Science team support activities; 2) SeaWiFS solar-based calibration; 3) Cross-calibration radiometer; 4) Reflectomobile; 5) Mobile laboratory; 6) Shortwave infrared (SWIR) radiometer; 7) Bi-directional reflectance distribution function (BRDF) meter; 8) Cary spectrophotometer and laboratory calibration; 9) Algorithm and code development; and 10) Field experiments.

Science Team Support Activities: This section refers to all work performed in support of MODIS and ASTER team activities as well as work performed for other sensor teams. Over the past six months this included the attendance at team and other related meetings and completing assigned action items,

ASTER Activities: S. Biggar and K. Thome travelled to Flagstaff, Arizona on January 13-14 to meet with H. Kieffer and K. Edwards of the USGS and G. Geller, S. Hook, M. Pniel, and C. Voge of JPL to discuss Level 1 processing of ASTER data. Biggar, P. Slater, and Thome attended the Joint ASTER Team Meeting in Las Vegas, February 1-5. Slater presented work being done on combining pre-flight, on-board, and ground-based calibration methods to obtain an appropriately weighted, best estimate of in-flight absolute calibration as a function of time. This work is applicable to both ASTER and MODIS. Biggar presented his work on the transfer-absolute radiometer and Thome gave a presentation on atmospheric correction in the solar reflective range. Slater attended the ASTER Calibration Peer Review and the ASTER PDR Report meeting in Japan March 6-15.

Biggar sent to then ASTER team leader A. Ono information regarding MODIS on-board calibration and suggestions for measuring the polarization sensitivity of the VNIR and SWIR sensors. Thome faxed H. Lang of JPL comments regarding a preliminary study of DEM requirements for atmospheric correction in the solar reflective region. Biggar and Thome compiled and sent Hook information regarding anticipated test sites to be used by the Remote Sensing Group. Thome also sent him a brief algorithm description for the atmospheric correction in the solar reflective region.

Slater sent a report to JPL summarizing the status of ASTER calibration. Thome aided Geller in writing the ASTER Systems Concept Document.

MODIS Activities: Biggar and Slater attended the Eos Calibration Panel Cross-Calibration meeting in San Diego January 28-30 where Biggar presented our cross-calibration plans and calibration ground test sites. Biggar and Slater also attended the MODIS Team meeting March 22-26 in Washington, D. C. Biggar presented an update of his work on the VNIR transfer radiometer and described the preflight solar calibration of SeaWiFS. Slater reviewed the MCST plans for calibration and initiated action for a peer-review of these plans. Biggar and Slater also attended the Cal-Val Round-Robin planning meeting at NIST on May 18. Slater attended the MODIS Technical Team meeting held May 20, the MCST Steering Committee meeting, May 21, and the MISR Cal Peer Review in Pasadena, May 24-25. He also attended an MCST workshop at the University of Maryland on June 17 and reviewed the first draft of the MOIDS Alogorithm and Theoretical Basis Document with J. Barker on June 21 and later. He is presently reviewing Version 0 dated June 24.

Other Eos Related Activities: Biggar, Slater, and K. Thome attended the aerosol workshop sponsored by Goddard, May 17-18 in Greenbelt. M. Brownlee and P. Slater travelled to Washington, D. C. for the NASA Headquarters Graduate Students Researcher Program Symposium in Washington D. C., May 10-14, where Brownlee presented a poster on the BRDF camera. Biggar attended the Infrared and Visible Optical Sensors sub-group meeting of the WGCV of CEOS at the Joint Research Center in Ispra, Italy starting May 31. Slater and Thome travelled to Torrance, Calif. for the DLPO Workshop on Atmospheric Correction of Landsat Imagery where Thome presented plans for the atmospheric correction of ASTER in the solar reflective portion of the spectrum.

SeaWiFS Activities: Slater attended the SeaWiFS meeting in Annapolis, Maryland from January 19-22 where he presented several concepts for performing a preflight calibration using the sun as a source. As a result of this talk Biggar and Thome travelled to Santa Barbara, March 6-9 to aid SBRC in a solar-based, preflight calibration of SeaWiFS. Further information and results of this experiment are given in the next section of this report. Slater attended the SeaWiFS pre-ship review at Santa Barbara Research Corporation on April 27.

Several members of the group traveled to Orlando for SPIE's International Symposium on Optical Engineering and Photonics in Aerospace and Remote Sensing. Eight papers were presented by various members including presentations by Biggar on the cross-calibration radiometer and the SeaWiFS solar-based calibration. D. Gellman presented results of work relating the on-board-lamp calibrator on SPOT to calibration coefficients obtained from the reflectance-based method. J Palmer and Thome presented papers on the recent calibration of Landsat-5 TM, with Palmer giving the results for the thermal and Thome those for the solar-reflective portions of the spectrum. Reprints of all papers presented are available on request.

SeaWiFS Solar-Based Calibration: The objective of this project is the pre-flight calibration of the SeaWiFS sensor using the sun. The idea for such a project was first raised by Slater at the SeaWiFS Science Team Meeting in January of this year.

The hour-long calibration was conducted at SBRC on March 8, 1993 by Biggar and Thome aided by A. Holmes and SBRC staff. The procedure was to situate the sensor such that the solar diffuser was illuminated in the same geometry as it will be in orbit during calibration. When the diffuser was aligned correctly, the digital counts from the sensor while it was viewing the diffuser were recorded for each spectral band. Then the diffuser was shadowed by a small disk that blocked the direct beam and the digital counts were again recorded for each band. The difference, corrected for the atmospheric transmittance and the small component of diffuse light blocked by the disk, corresponds to the in-orbit illumination of the diffuser. A photograph showing the SeaWiFS sensor being shaded is given in Figure 1. The atmospheric transmittance was measured during the period of diffuser measurements with a solar radiometer.

Error analysis of the method indicates the results should have a 1s uncertainty of less than 2.8% for all of the SeaWiFS wavelengths. The primary source of error in the method is the atmospheric transmittance as measured by the solar radiometer. To reduce this uncertainty, B. Crowther, Gellman, and Thome travelled to Mt. Lemmon to calibrate the radiometer used in the SeaWiFS calibration. The filters from this instrument were also sent out to be scanned to determine their spectral-transmittance properties.

Band #	Gain Setting	Transmittance	Unshaded DCs	Shaded DCs	Forward scatter DCs	Predicted in-flight DCs	Sphere-derived DCs
1	2	0.567	420	21	1	701	708
2	3	0.634	355	17	1	532	546
3	3	0.708	484	19	1	655	670
4	4	0.728	737	28	2	972	1004
5	1	0.763	618	23	1	778	808
6	4	0.836	625	22	1	720	730
7	4	0.799	581	21	1	699	729

The results of solar-based SeaWiFS calibration are given in Table 1. The unshaded and shaded DC columns are the digital counts reported by SeaWiFS while viewing the solar diffuser without and with the presence of the shading disk shown in Figure 1. The predicted in-flight DCs column is the calibration result expected on space from the solar diffuser. Also given in the table are predicted digital counts based on measurements using the SBRC 100-cm integrating sphere. The results are encouraging as the difference is less than 4% for all bands except for band 8. The 7.7% difference in band 8 requires further analysis to determine the cause for the difference.

In reviewing the results, it should be realized that there are many error sources associated with both the sphere-derived and solar-based calibrations. The two that are the hardest to define are those of the solar-exo-atmospheric-spectral irradiance and the spectral irradiance of the lamp used to calibrate the sphere. It is felt that the success of the Eos project depends partly on resolving the issue of these errors.

The success of this experiment has prompted interest in its use for MODIS calibration. However, the success of this type of approach must also be weighed against the risks of exposing the satellite sensor to an outdoor environment. We feel that with proper planning and care, most of these risks can be minimized to a point where this method of calibration is worthwhile. More detailed information regarding this technique may be found in Biggar et al., 1993.

Cross-Calibration Radiometer: The objective of this project is to design and build a 400 to 900 nm cross-calibration radiometer, test this radiometer, and write control and data acquisition software. This radiometer will provide an independent calibration and cross-calibration of radiance sources used by Phase C/D contractors. Biggar designed the radiometer with three silicon detectors in a "trap" configuration. Spectral selection is through interference filters selected by manually turning a filter wheel. Two precision apertures determine the throughput. Heating the detector assembly, filters, apertures, and amplifier to a stabilized temperature a few degrees above ambient provides thermal control of the system. A commercial datalogger digitizes the amplifier output and ancillary information such as detector temperature and controls the amplifier gain through digital output ports. This datalogger sends the serial digital data to a MS-DOS compatible computer. The entire radiometer consists of the head with filter wheel, the electronics/power supply package, connecting cables, datalogger, and computer.

Biggar completed assembly of the absolute radiometer's power/control module in preparation for preliminary SNR measurements. He received the filters for the absolute radiometer and had them scanned to determine their spectral transmittance properties. He also measured the apertures of the instrument with a precision-travelling microscope, completed preliminary dark current tests, and tested the data acquisition software. The radiometer was taken to SBRC in conjunction with the above-mentioned SeaWiFS trip and placed in front of SBRC's integrating sphere. Biggar analyzed the data from this experiment and presented a paper on the results, as well as a description of the radiometer itself, at the April SPIE meeting.

Tests of the radiometer continued by taking the instrument to EG & G in Las Vegas for measurements in front of their 40" integrating sphere source. No useable data were collected because of a malfunction in the source's power supply. Biggar also used the radiometer to measure the Labsphere 1.6 m diameter integrating sphere used for the pre-flight calibration of SPOT-3 and 5 other smaller spheres as part of the SeaWiFS Calibration Round-Robin activities held in San Diego, June 21-25.

Reflectomobile: The task objective is to design a vehicle and instrument package to perform surface reflectance measurements more accurately and repeatably with only one person. In the past, people have carried yokes which extend the radiometers away from the walker's body to reduce shadow and other problems. This method requires the involvement of at least three people, takes about 40 minutes to cover a 0.02 km^2 site, and depends on the ability of the walker to orient the radiometer correctly. Construction of the reflectomobile is complete but tests and modifications continue.

As part of a test of the reflectomobile, we measured surface reflectance of the Chuck Site SPOT transect twice on 1992.12.14. Figure 2 shows the repeatability of these measurements. Only the influence of shadow in the third leg shifted one curve with respect to the other. It should be noted that while there is a definite variation in reflectance versus pixel number, the MMR has repeatably characterized it. Thus, the uncertainty in surface reflectance should be not be taken from the standard deviation of the measurements within a set, but rather from the variation between redundant sets of measurements.

As part of the White Sands trip in April, mentioned in section 10, Gellman modified the reflectomobile to accept the French contingent's equipment by mounting it to the side of the space frame ordinarily taken by counterweight. This arrangement succeeded, with one problem that was overcome. When the French equipment was removed and the reflectomobile driven without counterweight, an attachment point on the space frame failed. Spare parts were on hand, and the failure did not compromise the experiment. Future work on the reflectomobile will improve the design of the attachment point where the failure occurred.

In future work, Gellman will also ensure that the reflectomobile can be used with the instruments swung away from shadows without giving up stability. The reflectomobile might undergo a significant redesign if the mobile laboratory's (see next section) tow vehicle can be freed for reflectance measurements. If we decide that the tow vehicle (a pickup truck) is appropriate, we would attach the space frame to its stake pockets instead of to the flat trailer we now use. At this stage, we can only speculate on the suitability of this approach, because we have only now ordered the merchandise for the mobile laboratory and its tow vehicle.

Mobile Laboratory: The objective of this task is to design a mobile laboratory for 1) storage and transportation for equipment; 2) electricity (AC and DC) for equipment; 3) shelter from the sun, heat, and cold for computers and people during measurements and for all our equipment overnight at experiment sites; and 4) a roof platform for certain instruments, especially the solar aureole meter and some meteorological instruments.

Gellman used these criteria to design the proposed version of the mobile laboratory. We intend it to consist of a fifth-wheel, gooseneck trailer towed by a pickup truck with dual rear wheels. With this arrangement we could detach the mobile laboratory at the site during multiple-day experiments; use the tow vehicle for reflectance measurements; and substitute a different tow vehicle if the pickup truck breaks down. We are in the purchasing stage of the laboratory and the preliminary designs could change. We anticipate having a completed version of it by the end of this year.

SWIR spectroradiometer: The objective of this task is to design and construct an instrument to measure surface reflectance in the SWIR region of the spectrum. When our contract began, M. W. Smith had already designed and built the prototype.

Crowther and S. Schaeffer installed thermoelectric temperature stabilization of the diffraction housing to reduce the dark current. The thermoelectric coolers originally intended to cool and stabilize the temperature did not provide enough cooling. Schaeffer insulated the grating housing but this proved insufficient. More powerful TE coolers were ordered and installed. These new coolers provided enough cooling at room temperature but proved insufficient at higher ambient temperatures. To remedy this, a larger heat sink was installed and this heat sink is cooled by dry ice.

Another problem was encountered on the April White Sands trip when it was discovered that the fluoride fiber optic had been broken, making it inoperable for the trip. A replacement is being considered which will allow the spectrometer to be mounted to the reflectombile. Other future work includes creating a mount for the instrument on the reflectomobile, further field testing, and comparisons with other instrumentation. The reflectance retrieval software will be developed and a user manual will be written.

BRDF Meter: The objective for this task is to design and construct a device and develop software for measuring the directional reflectance and inferring the bi-directional reflectance distribution function of the ground. The basic design incorporates a fisheye lens and a CCD-array detector.

The Photometrics camera arrived as did the computer used for data collection. Work began on mounting the Nikon fisheye lens to the camera and interfacing to the computer which arrived during the reporting period. Brownlee performed preliminary tests of the computer/instrument interface. She also continued work on the instrument's filter specifications. Anticipated activities include completing tests of the computer/instrument interface, development of data acquisition software, and ordering the interference filters.

Cary Spectrophotometer and Laboratory Calibration: The objective of this project is to refurbish a Cary 14 spectrophotometer for use in the laboratory. J. Palmer continued refurbishing the spectrophotometer. He also took delivery of a vibration-isolated optical table and spectroradiometer monochromator to be used for detector calibration.

Algorithm and Code Development: This section is broken into three parts. The first part discusses work relating to the thermal infrared (TIR) portion of the spectrum. The second covers the algorithms and code used in the visible and NIR. The last section discusses software development not covered in the first two. In related activities, Thome began work on the Algorithm and Theoretical Basis Document for the in-flight calibration of MODIS.

TIR: Currently, several algorithms exist to perform work in the TIR portion of the spectrum. The task is then to determine which of these algorithms best fits the current problem. Palmer processed the ground data from the August 1992 White Sands trip and compared it to that obtained by Landsat. Palmer presented the results of this calibration at the SPIE meeting in April. A detailed description of this method and the results may be found in this paper.

Visible and NIR: Currently, several algorithms exist to perform work in this portion of the spectrum. The RSG has applied these algorithms as FORTRAN programs which are neither user friendly nor efficiently linked together into a single package. The task objective is to convert these existing codes into ANSI standard C in a user-friendly package with rules-based decision making in the package. The group is now also developing the algorithms and software for the atmospheric correction of ASTER data in the solar reflective portion of the spectrum.

Thome and H. He read the Landsat-5 TM Level 0 data from the August White Sands calibration campaign and used the data in a visible and near-infrared calibration of TM, the results of which were presented at SPIE. Thome also presented the planned method for the atmospheric correction of ASTER at the DLPO Workshop on Atmospheric Correction of Landsat Imagery. Work on the data flow diagrams for the atmospheric correction and the in-flight calibration algorithms continued.

Thome will develop the prototype version of the atmospheric correction for ASTER in the solar reflective region. Related to this work, Thome will investigate test criteria for selecting between the Japanese Science Team's atmospheric correction algorithm and the American team's. A sensitivity analysis of the atmospheric correction to errors from input data will be performed and sent to the team leader. Prototype versions of the in-flight calibration software will also be developed. User's guides and test data sets will be developed for the prototype codes.

Other software development: Gellman and Slater worked on combining pre-flight, on-board, and ground-based calibration methods to obtain an appropriately weighted, best estimate of in-flight absolute calibration as a function of time. Gellman presented results of this work as applied to SPOTs-1 and -2 at SPIE, though the method can be used to unite multiple calibration sources for MODIS as well. Gellman developed software to reduce reflectance data collected by our Spectron spectrometer. He also wrote software to compute the position of the sun, in order to compensate for the recent lack of support in this area from the U. S. Naval Observatory. System administration work was performed by He, who also continued developing software to read satellite tape images onto the UNIX-based-Sun network.

Field Experiments: The objectives of the field experiments are to test new equipment, determine needed improvements, test retrieval algorithms and code, and monitor existing satellites in much the same way as we shall for Eos sensors. During the six-month period, the RSG made one trip to White Sands Missile Range, the previously described SeaWiFS calibration, and an equipment calibration trip to Mt. Lemmon. The group also processed data in support of S. Soorooshian's EOS interdisciplinary project in the Walnut Gulch watershed in Arizona and MODIS Science Team Member A. Huete.

Several members of the group travelled to White Sands the first week of April. Gellman, Slater and Thome were accompanied by graduate students, Crowther, R. Parada, and K. Scott. The RSG members were also accompanied by several French scientists as well. The trip concentrated on testing equipment, cross-comparisons with the French instruments, bi-directional reflectance measurements, and a calibration of SPOT-2. Equipment tested included the SWIR spectrometer, a VNIR spectrometer, and the reflectomobile.

A field experiment is planned for the fall of this year at White Sands. This trip will be used for a SPOT-2 calibration as well as for JERS-1 and possibly SPOT-3.